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**US Army Corps  
of Engineers**

Hydrologic Engineering Center

**AD-A273 256**



# Issues for Applications Developers

Technical Paper No. 139

January 1993

Approved for Public Release. Distribution Unlimi

**93-29286**



93 11 22 10

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## Issues for Applications Developers<sup>1</sup>

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### SUMMARY

Development of the right applications software for the water industry that is robust, flexible, maintainable, and portable requires a strategy that determines user needs, creates software in a develop, test, user feedback process, and includes training and support. Software engineering decisions related to the choice of engineering methodologies, program architecture, coding languages, graphics and other support libraries, and adoption of hardware and software industry standards are critical to success. Development of engineering applications software is best accomplished by organizations with experience in both the problem addressed and software development and support.

### 1. INTRODUCTION

Applications software are important tools used by the water resources community for planning, design and operation of water resource projects. Desktop hardware, operating systems, coding languages, and a myriad of other factors have evolved such that the traditional applications development environment of an engineer writing FORTRAN code is no longer appropriate. The software used in the coming decade will be highly sophisticated from a technical standpoint, constructed specifically for the user environment, and include advanced graphical display capabilities.

There are several important questions for the water engineering community to address. What should the software do? How and in which environment should it function? How should this be determined? Who should develop this software? Who (and how) should support the software? How can the profession ensure that user needs will be adequately reflected? The answers to these questions are of interest because a new generation of applications software is under development by governments, academia, and the commercial sector. This paper summarizes "truisms" related to engineering software development and technology transfer and offers commentary related to these questions.

### 2. A PROVEN SOFTWARE DEVELOPMENT STRATEGY

A method for successfully accomplishing software development, implementation and servicing is as follows: a) need for new methods and procedures surface through solving real-world problems and maintaining contacts with the user community, b) research and development work is performed to solve specific problems, c) solutions are generalized so that they may service other problems, d) high quality documentation is developed and software is prepared for long term service and maintenance, e) training courses are held and consultation projects performed that gradually, but systematically, move the software into every day work of users, and f) continuing development, servicing and maintenance are performed to assure aid to users and guarantee up-to-date capabilities are incorporated.

#### 2.1 Observations for Applications Package Developers

Several "truisms" have emerged that are applicable to the development and implementation of engineering applications packages. These observations are directed to a unit in an institution (public or private) that is developing new applications software and provides service and support to in-house and other users.

- a) Large scale, complex, comprehensive computer programs are dynamic entities that

<sup>1</sup> Invited Keynote Presentation at WATERCOMP '93, 2nd Australasian Conference on Computing for the Water Industry - Today and Tomorrow, 30 March - 1 April 1993, Melbourne, Australia.

require continuous nurturing and support in order to remain viable and useful. Such computer software needs a permanent home; an institution that is philosophically committed to the improvement in procedures, morally committed to servicing and improving the programs, competently staffed to perform that task, and available "on call" to users.

b) Professionally developed computer program code and its management is vital for software to be effectively maintained and be portable among hardware platforms. Use of special purpose languages that are proprietary or are not generally within platform and software industry standards should be avoided. Adherence to "standards" such as American National Standards Institute (ANSI) language standards is important and use of modern programming practice is needed to minimize difficulties in computer source code maintenance.

c) Successful implementation of advanced applications packages requires both useful technology available in appropriate form and users that are interested and anxious to take advantage of the opportunities. It is important in early stages to encourage applications that are manageable and have potential for success. A commitment to a service attitude and genuine interest in solving user community specific problems are basic.

A series of do's and do not's with supporting explanation follows which attempts to define a framework and strategy for applications software development and implementation.

a) Engineering management should not "require" applications packages to be used before considerable experience and shake-down is accomplished. Nothing kills interest in a new package like forced use that does not deliver the solution to everyone's problems. New applications packages can not be so tightly developed that they can survive an environment wherein the potential users are put in a negative posture by the forced approach. A pragmatic, steady, gradual introduction will likely result in early, meaningful use of the concepts and techniques. Nothing draws users like success, no matter how small.

b) Avoid (if possible) the grand "demonstration" exercise. Application demonstrations designed to sell technology often get too many people involved with parochial agendas. The exercise often becomes rigged or fails because of the weight of so many observers. Dissemination of basic information through publicizing applications is useful. Including sessions on the application in seminars, general meetings, and training courses is an excellent method for exposing applications packages to potential users.

c) Work With users to solve their problems. A full commitment to solving the users problem is perhaps the single most important facet of successful technology transfer. An approach that solves specific problems from which the elements are continuously merged into an analytical system is more responsive to user needs than creating a grand solution that is then adapted to a specific problem. It is not unusual for an application to have some unique twist. Early implementation efforts should seek to work with users on specific studies.

d) Carefully select manageable studies or portions of studies for initial applications. This is the operational implementation of the idea that nothing draws users like success, no matter how small. The selection of small well-defined problems that both developers and users can learn from and thus improve the program is important. A poor strategy attempts to "solve the unsolvable" as an early application. There are always difficult problems needing solution; build an experience base before stretching too far. A series of small, growing to more comprehensive and difficult applications over time is the desired strategy.

e) Be prepared and willing to perform logic and program code changes for early studies. Developers usually can not foresee all potential study environments, objectives, data availability, issues, etc. for which the software might be used. Design deficiencies, bugs, and errors will exist. The attitude and ready resources to make the necessary adjustments will reflect the commitment to a services approach to implementation.

## 2.2 Observations for Applications Package Users

The successful user is one that is confronted with a problem, has struggled to find a solution, and recognizes that it could be at least partially addressed with the applications package. The unsuccessful user is often the recipient of an applications package provided by a colleague or superior. The colleague or superior was probably introduced to the software in a general way and became convinced that it must surely have value, especially if appropriately used by others, (the user) to solve his problems. With these positions defined, a few comments are offered below.

a) Know problems and needs in detail. There is a tendency for users, especially those who are not highly computer oriented, to end up with their problems becoming defined by the performance capabilities of a particular software package. This results in a reverse approach to acquiring a high technology solution to a problem and is usually not the best approach.

b) Determine how the problem should be solved irrespective of the capabilities of applications packages. Sophisticated applications packages require considerable commitment of resources, both dollars and manpower. The potential user should make certain that resources are effectively used to accomplish the problem solution that generated the search for the applications package.

c) Thoroughly investigate features and capabilities of alternative applications packages. Applications packages come in integrated hardware-software arrangements, software alone, or just specific-task oriented software. Important issues are propriety of the package (Is a license required and what are the costs and restrictions?), specialized nature of hardware platforms and peripherals, software package adherence to standards, documentation, service, training, and compatibility with existing and future equipment and people. What is right for one circumstance may not be relevant to another.

d) Do not expect magic. Applications packages performance between hardware and system environments can vary greatly. While one should prudently seek a package that has a record of minimum difficulties, it is best to plan for at least some start-up time and remain flexible. Start-up should be well planned and involve user representatives.

e) Willingly commit the personnel resources to "own" the applications package. A major shortcoming in the effective use of sophisticated applications packages is the unwillingness of potential users to devote adequate time and energy to "own" the software package in an applications sense. Most capable engineering applications packages are sufficiently sophisticated that continuous use and familiarity by the users is needed to maintain effectiveness.

f) Continuously ask questions of the developers and user supporters. Probe the limits of capabilities, and presume sophisticated software should be continually adapted and improved over time. A package frozen in capability from installation date is one that will soon be unresponsive to the needs of the users. When evaluating and using engineering products, it is of primary importance that the user truly understand the product. A first-rate engineer that truly knows what he is doing will likely produce a better solution using a second-rate applications product, than a second-rate engineer could do using a first-rate applications product he doesn't understand well.

## 3. DEVELOPING THE RIGHT APPLICATIONS PACKAGE

Determining user needs is the critical first step in the development of a successful applications package. Software engineering, a discipline that addresses the complete software development cycle, continues to propose, test, and refine strategies for ensuring successful software development projects. A popular software engineering approach often referred to as the "waterfall model" includes performing the following: requirements analysis, preliminary and final design, coding, testing, deployment, and service and support. The process is conceived of as once through, beginning to end, permitting an efficient, manageable, production oriented approach.

Users define the needs and software specialists design, code, test, and deploy the product. Some interaction with users is anticipated during the development process.

Experience suggests that while this approach is a useful framework, development of successful engineering applications software is best served by a less formally structured, multi-pass approach. The organization and its staff that is assigned the development project is important. Organizations and staff that have experience in performing studies in the technical area of interest, developing and deploying applications packages, and training and support are best suited to performing the work.

The requirements analysis step is useful and essential. Preliminary requirements are defined by a development team in consultation with a selected group of user representatives. The preliminary requirements are documented and circulated among a larger user group for comments and input. Final requirements are then prepared by the developers in consultation with the selected group of users. Development of a prototype (or limited-scope preliminary version) can be very helpful at this stage by providing a real, functioning program (as compared to a paper plan) to which potential users may respond. A certain amount of design will have taken place during the prototype development. Its best to take time to perform a complete conceptual design that will be tested in the prototype development. Flexibility for future improvements key.

Development of the applications package can then be undertaken as a production process. For a sophisticated and capable engineering applications package, the development team should be comprised of a specialist in the technical applications area (often the team leader), and a complement of computer scientists, programmers, and consultants. In today's technology environment, the development of an engineering applications product requires the combined talents of knowledgeable engineer-practitioners and skilled computer science specialists. It is no longer possible for a few engineers to possess the broad range of skills necessary to produce a satisfactory product. Not all team members need to be full-time on the project. The consultants may be from other groups in the organization or procured via contract to provide limited scope, highly specialized knowledge that is essential in the extremely capability-rich yet complex hardware and systems environment.

Development should be staged so that usable products emerge in a regular manner throughout the development period. Product releases should be often enough to provide the user community with the opportunity to observe progress and provide feedback on needed capabilities, but not so often as to create a climate of turmoil and distraction for the developers. Six-month intervals is probably too short with one-year intervals about right. The first release after the prototype should be a preliminary yet fully functional package. Early releases should be to selected users that are willing to apply the package to real problems but who are familiar with software development so that difficulties that will arise are not unexpected.

#### **4. HARDWARE, OPERATING SYSTEM, CODING, AND RELATED STANDARDS**

Today the typical engineering computing environment has become the desktop machine. It is likely to be a high-end personal computer with an Intel 486 processor (soon to be succeeded by P5), or a RISC-chip based engineering workstation (or X-Terminal to a workstation) equipped with a high resolution color monitor. The desktop machine is connected to other workstations, file servers, laser printers, plotters and other devices via a local area network. In some instances, access to regional centers and other national and international sites is available through network gateways to world-wide communication facilities.

The software developer must design and develop applications packages to take advantage of the opportunities provided by this rich environment. Developers must be careful to avoid constructing applications that exhibit hardware and system dependencies that adversely affect code portability, future upgrades, and long-term servicing. Most software industry professionals and users generally agree that these notions are highly desirable; the goals are easy to articulate. The pay-off is in the successful translation into software development strategies, standards,

criteria, and ultimately computer code that achieves those goals.

#### 4.1 Hardware/operating System

Hardware and associated "chip" families, operating systems, and binary (compiled and linked) code compatibility are tightly connected. For example, MS-DOS [1] and Microsoft Windows [2] operate within the Intel-chip family of personal computers and thus binary code is compatible among machines. There are a variety of RISC chips that are used in workstations. Binary code is generally compatible within a chip family (vendor product line); for example among the IBM RISC-chip workstation line of computers, but not across chip/vendor computers. UNIX [3] is the standard operating system for RISC-chip engineering workstations providing code compatibility at the source (not binary) level. While this is not particularly important for the user, it is extremely important for program developers.

Minimum hardware configuration and specifications that can be expected for the engineering desktop for the next few years are as follows:

**Personal Computer:** Intel 486/66 mhz processor, 8 to 32 MB RAM, 200 to 600 MB disk, 14" Super VGA monitor, networked to plotters and printers, DOS/Windows operating environment.

**Workstation:** RISC-chip/50 mips processor, 32 MB RAM, 1 gigabyte disk, 17" monitor, networked to other workstations and peripherals locally and regionally, UNIX operating system.

For the personal computer, DOS has been the unquestioned standard for office automation applications. While there are a number of capable engineering applications packages running in DOS, the future seems to be toward multi-tasking, window-based systems. Candidates are Microsoft Windows (soon to be Windows NT [4]), OS/2 Presentation Manager [5], and UNIX. In the RISC-chip based workstation environment, UNIX is the standard, with the possibility that Windows NT might soon be a competitor for some chip families. It is important to maintain adherence to a standard, such as Posix [6] to ensure cross UNIX platform compatibility.

For the software developer, the issue is therefore what hardware configuration, likely operating systems, coding languages and associated compilers, third-party libraries, etc. will enable the desired performance, portability, upward compatibility, and service support needed for the applications package. The likelihood is that packages will need to be functional in both environments. The appropriate strategy to follow is to code the application using languages, libraries, utilities etc. that make it least painful to port to other platforms. This is easier said than done.

#### 4.2 Programming Philosophy, Languages, and Related Issues

The application package to be developed must ultimately be coded in a computer language, compiled, and linked into binary code for execution on a specific platform. Various programming strategies, languages, and use of commercial utilities and libraries are employed. Historically, engineering applications programs were developed by an engineer programming in FORTRAN and following the ANSI language standard. Often the program in current use was originally coded in FORTRAN II, with subsequent improvements coded in FORTRAN IV, 66, and 77 and ported and re-compiled for the successor generation platforms. This continued to be successful and relatively simple while programs read mostly number and character input and output the same.

The base engineering functions that implement the solution algorithms are becoming more and more transportable across a wide variety of chip families. This is true whether they are coded in FORTRAN, C [7], or another popular language. Data base access, graphical user interfaces (GUI), and visualization tend to inhibit transportability across platforms at the current time. New

languages have emerged responsive to the needs, and an impressive array of commercial libraries and higher level coding aides are available to be used by the programmer. While no definitive consensus has emerged, there are a number of logical strategies to consider in programming the applications package.

The graphical user interface is the boon and the bane of the programmer. It offers the opportunity to create a comfortable and highly productive user environment. The developer must be careful, however, to avoid dressing up a poor or outdated engineering solution with an attractive user interface. The engineering algorithms must be top-notch in order to warrant the considerable effort to create a productive GUI.

Most recently developed GUI are coded in C using standard Motif [8] and X Windows [9] library functions because of the platform portability and power in providing direct programmer control of the user-device interface. A programming concept referred to as object-oriented programming (OOP) [10] is emerging as an important player in the user interface, as well as other, programming areas. It's reported power is that of enabling the creation and manipulation of reusable coded objects that can substantially improve the robustness and maintainability of the software and productivity of the programmer. The coding language that is gaining a following for implementation of OOP is C++ [11]. A number of major commercial software vendors are reported to have adopted C++ for their own new program development. Motif and Open Look [12] provide widget libraries that prescribe a standard look and feel for constructing GUI's in the X Window system. X Windows is the de facto standard windowing system for the UNIX operating system. In the DOS environment, Microsoft Windows is dominant with IBM OS/2 Presentation Manager also a player.

Unfortunately, a GUI developed following standards in the UNIX workstation environment is not directly portable to Microsoft Windows, and vice versa. Since engineering applications packages will most likely need to function in both systems, a dilemma exists. One approach is to develop separate GUI's for each environment. While unattractive, its done in the commercial sector. Another is to use proprietary GUI builder libraries and cross platform compilers. This is also unattractive, perhaps even more so. The best approach seems to be to proceed with development following the prevailing standard in each (say Motif and Microsoft Windows), isolate the code related to the GUI from other program functions, and take care to be as consistent between both environments as possible. One also hopes that the next few years continues the trend toward a common operating system and attendant GUI standards that will serve both environments.

The majority (perhaps above 90%) of currently used engineering applications program "engines", the engineering algorithm solution portion of the program, are coded in FORTRAN. This is likely to continue for some time for new programs as well. This is both because engineering programs tend to be developed by engineers, and routines from the substantial inventory of functioning FORTRAN programs will be re-used in new programs. FORTRAN 90 [13], the next ANSI FORTRAN standard, offers new data structures, dynamic memory, and other desirable attributes. Some industry observers have suggested that future FORTRAN standards and extensions will implement OOP concepts more fully. A number of software development projects [14], are being developed with OOP concepts using C++ for the overall program architecture, C where necessary, and FORTRAN for some compute functions.

### 4.3 Graphics

Increasing use of display and output graphics (often referred to as visualization) is the emphasis for the future for engineering applications packages. Coding the graphics routines using primitive, basic level intrinsics from libraries may be logical and practical for mass market commercial software firms. It is not often practical for the more limited market of engineering applications programs. Making calls from the applications program to graphics functions routines is more common. The question then is which package of graphic function routines should be used? Again, the circumstance is complicated so the best choice is not obvious.



The choices reduce to selecting from commercial and public domain packages (there are quite a number) such as UNIRAS [15] and InterViews [16] that provide graphics products on-the-fly from simple program level calls. Decision factors include capability, licensing and fee arrangements, documentation and support, platform availability, and success history in the market place. All things being equal, one would select the package that has adequate capability, is in the public domain thus minimizing licensing and fee issues, is available for target workstation and personal computer platforms, and is reasonably documented and supported.

No package has emerged that has gained significant market acceptance that supports both workstation and personal computer platforms. If the application will be run only in the Microsoft Windows environment and the Windows graphics library is adequate, it is an attractive choice. This is not often the case but in the near term, it may be a reasonable alternative for the personal computer implementation of the applications package. The use of X Windows libraries provide such capabilities in the UNIX environment. No clearly dominant commercial or public domain high-level graphics support package has emerged for programming applications for either Microsoft windows or X Windows workstations. It is desirable that products be developed such that they may interface to still-higher level graphics capabilities available in geographic information systems packages.

#### 4.4 Data Base Support

An important issue for software development projects is providing for data persistence necessary to support the GUI, graphics, and technical analysis envisioned. Depending on the applications package, many data types must be addressed. These could include time-series, (hydrologic data), paired-function (x,y tabulations), model-parameter, stream-geometry, and spatial and image data. Data base management systems were created to meet such needs. The larger, more complex in scope the applications package, the more likely that significant amounts of data of several types might be important. No single data base system, commercial or private, seems to offer efficient management for the full range of data types. Commercial systems, for example ORACLE [17], offer great capability for managing relational data, but limited capability for time series data. Specialized systems, for example HEC-DSS [18], are optimized for time-series and paired-function data.

Developers should carefully analyze the data management needs for their specific applications package, and design early, the approach to be taken. The increasing availability of industry-wide and regional data bases that may be useful for application packages warrants consideration in program design. Also, the need to share (or pass to the next step in design), engineering data is an issue that should be considered as well. Whether to design a custom-coding solution, or choose from commercial and public domain data base packages is a decision that should consider portability, license and run-time fees, programmer effort to implement, and requirements for long term service and support.

#### 5. CONCLUSIONS

Successful development of the right engineering applications software packages requires adopting a strategy that determines user needs, and accomplishes development in a develop, test, user feedback process. Application package development should be performed by organizations that have experience in solving engineering problems in the field, experience in developing, deploying, maintaining and supporting applications software, and are committed to a services approach to users. The development team should be comprised of a technical specialist in the applications area, and a complement of computer scientists and programmers. The engineering desktop platforms for the next few years includes high-end Intel-chip personal computers and RISC-chip based workstations. Use of modern software architecture concepts to include OOP, application of standard programming languages, and adherence to published software standards (where they exist) and de-facto industry standards is essential to ensure successful applications package development.

## 6. ACKNOWLEDGEMENTS

The views expressed in this paper are a synthesis of the experience of the staff of the Hydrologic Engineering Center. This experience was gained from 25 years of developing and supporting engineering applications software for the U.S Army Corps of Engineers.

## 7. REFERENCES

1. Microsoft Corporation, "MS-DOS User's Guide and Reference Version 5.0", Microsoft Corporation, 1991.
2. Microsoft Corporation, "Microsoft Windows Version 3.1 User's Guide", Microsoft Corporation, 1992.
3. Rosen, Kenneth H., Rosinski, Richard, R., and Farber, James M., "UNIX System V Release 4: An Introduction", Osborne McGraw-Hill, 1990.
4. Microsoft Corporation, "Microsoft WIN32 SDK for Windows NT (Preliminary)", Microsoft Corporation, 1992.
5. IBM Corp., "Operating System/2 Standard Edition User's Reference", IBM Corp., 1987.
6. Levine, Donald A., "Posix Programmer's Guide", O'Reilly & Associates Inc., 1991.
7. Kernigham, Brian W., Ritchie, Dennis M., "The C Programming Language", Prentice Hall, 1988.
8. Open Software Foundation, "OSF/Motif Programmer's Reference", Prentice Hall, 1991.
9. Asente, Paul, and Swich, Ralph, "The X Window System Toolkit", DEC Press, 1990.
10. Cox, B., "Object-Oriented Programming: An Evolutionary Approach", Addison-Wesley, 1986.
11. Ellis, Margaret A., and Stroustrup, Bjarne, "The Annotated C++ Reference Manual", Addison-Wesley, 1990.
12. Sun Microsystems, Inc., "OPEN LOOK Graphical User Interface Functional Specification", Sun Microsystems, Inc., 1989.
13. Microsoft Corporation, "Microsoft FORTRAN Version 5.1 Reference Guide", Microsoft Corporation, 1992.
14. Davis, Darryl W., "The HEC NexGen Software Development Project", Proceedings of Watercomp93, The Institution of Engineers, Australia, 1993.
15. UNIRAS A/S, "agX/Toolmaster Reference Manual", UNIRAS A/S, 1991.
16. Linton, Mark A., Vlissides, John M., and Calder, Paul R., "Composing User Interfaces with InterViews", IEEE Computer, Vol. 22, No.2, 1989.
17. Oracle Corporation, "Professional ORACLE 5.1A Reference Manual", Oracle Corporation, 1988.
18. USACE Hydrologic Engineering Center, "HEC-DSS User's guide and Utility Program Manuals", 1990.

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REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED			1b. RESTRICTIVE MARKINGS		
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION / AVAILABILITY OF REPORT UNLIMITED		
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE					
4. PERFORMING ORGANIZATION REPORT NUMBER(S) TECHNICAL PAPER NO. 139			5. MONITORING ORGANIZATION REPORT NUMBER(S)		
6a. NAME OF PERFORMING ORGANIZATION HYDROLOGIC ENGINEERING CENTER USA CORPS OF ENGINEERS		6b. OFFICE SYMBOL (If applicable) CEWRC-HEC	7a. NAME OF MONITORING ORGANIZATION		
6c. ADDRESS (City, State, and ZIP Code) 609 SECOND STREET DAVIS, CA 95616-4687			7b. ADDRESS (City, State, and ZIP Code)		
8a. NAME OF FUNDING / SPONSORING ORGANIZATION WATER RESOURCES SUPPORT CENTER		8b. OFFICE SYMBOL (If applicable) CEWRC	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER		
8c. ADDRESS (City, State, and ZIP Code) CASEY BUILDING # 2594 FT BELVOIR, VA 22060-5586			10. SOURCE OF FUNDING NUMBERS		
			PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.
11. TITLE (Include Security Classification) Issues for Applications Developers					
12. PERSONAL AUTHOR(S) DARRYL W. DAVIS					
13a. TYPE OF REPORT TECHNICAL PAPER		13b. TIME COVERED FROM _____ TO _____		14. DATE OF REPORT (Year, Month, Day) 1993 JANUARY	
15. PAGE COUNT 11					
16. SUPPLEMENTARY NOTATION					
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) computer software, computer applications, computer models, water resources, hydrology, hydraulics		
FIELD	GROUP	SUB-GROUP			
19. ABSTRACT (Continue on reverse if necessary and identify by block number) Development of the right applications software for the water industry that is robust, flexible, maintainable, and portable requires a strategy that determines user needs, creates software in a develop, test, user feedback process, and includes training and support. Software engineering decisions related to the choice of engineering methodologies, program architecture, coding languages, graphics and other support libraries, and adoption of hardware and software industry standards are critical to success. Development of engineering applications software is best accomplished by organizations with experience in both the problem addressed and software development and support.					
20. DISTRIBUTION / AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED		
22a. NAME OF RESPONSIBLE INDIVIDUAL DARRYL W. DAVIS			22b. TELEPHONE (Include Area Code) (916) 756-1104		22c. OFFICE SYMBOL CEWRC-HEC